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Rhynchotalona latens (Sarmaja-Korjonen, Hakojärvi et Korhola 2000) (Crustacea, Anomopoda, Chydoridae) in Lacustrine Sediments of European Russia

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Abstract: Remains of *Rhynchotalona latens* (Sarmaja-Korjonen, Hakojärvi et Korhola 2000) were found in the bottom sediments of several glaciogenic lakes in northwestern Russia. Subfossil remains of the species were noted both in the bottom sediments of the Late Pleistocene and Mid-Holocene. We discovered a rare species, *R. latens*, in the bottom sediments of Lake Medvedevskoye (Karelian Isthmus). This species prefers shallow oligo-mesotrophic lakes with organic sediments and has attracted the interest of scientists around the world as it is considered a glacial relict and has recently been found in surface sediments and as a living population in Finland and Russia.

Keywords: Cladocera; Holocene; *Rhynchotalona latens*; lake sediments; European part of Russia

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1. Introduction

The existence of the species *Rhynchotalona latens* (Sarmaja-Korjonen, Hakojärvi et Korhola 2000) (described as *Unapertura latens*) [1] was previously known exclusively from paleoecological studies of Quaternary bottom sediments of lakes [2]. This was possible because of the preserved remains of the chitinous exoskeleton of Cladocera [3,4]. However, this species has recently attracted particular interest among taxonomists and paleoecologists [1,5,6]. The species was thought to be a glacial relict associated with modern analogues in periglacial aquatic environments. Researchers are working to refine the taxonomy, morphology, ecology, and biogeography of the species [5]. *Rhynchotalona latens* is of interest also because of its peculiar geographical distribution. Previously, chitinous remains of the species were found only in lakes in Finland, and the species was considered absent in modern zooplankton. However, recent studies have shown that the species is not endemic to Finland and is not extinct at all [5,6]. Both chitinized remains in lake surface sediments as well as actual specimens in Finland and Russia have proven that the species is present in modern cladoceran communities [5–7]. This is confirmed by the recording of this species in the surface sediments in the Pechora River delta (N 68°21′454″ E 053°24′759″) [8]. Moreover, an active population of the species was recently found in North Karelia [7]. *Rhynchotalona latens* prefers acidic, mesotrophic, humic, and shallow lakes with organic sediments in northeast Lapland, inhabiting waterlogged *Sphagnum* mosses at lake margins [5,7]. According to the latest information on the ecology of the species, *R. latens* does not occur in the littoral zone of lakes [7]; however, previous studies have shown that the species is found in semi-aquatic wetlands, lush lake littorals, and clear and cold waters [5,6,9,10]. At the northern end of its geographical distribution (NE Lapland), it reproduces with abundant gamogenesis under environmental stress [5]. *Rhynchotalona latens* has a Holarctic northern–alpine distribution [5] and has not been previously identified in paleolimnological studies in Russia. For the first time, we discovered *R. latens* in 2015 in the bottom sediments of Lake Medvedevskoye (Karelian Isthmus) [11]. Our latest findings of this species in bottom sediments are from the Kola–Karelian region of Russia and the central part of European Russia. Our research has allowed us to obtain new information about the distribution of *R. latens*, identify its preferred ecological and climatic conditions, and supplement the taxonomic lists of the order Cladocera in Russia.

2. Materials and Methods

The material for the study was sampled from the bottom sediments of seven glaciogenic lakes of European Russia (Table 1). The bottom sediments were selected by employees of the Kazan Federal University in joint expeditions with employees of the Northern Water Problems Institute at the Karelian Research Institute of the Russian Academy of Sciences, the University of Tartu (Estonia), and the Herzen State Pedagogical University using a Russian peat drill and Uwitec (Mondsee, Austria) and Limnos (Limnos Ltd., Turku, Finland) sediment samplers. The samples were prepared according to the method first proposed by Frey [12] and Hann [13] and later improved by Korhola and Rautio [14]. In the laboratory, suspensions of wet precipitate were dissolved in a 10% KOH solution, heated to 75 °C for 30 min, then filtered through sieves with a mesh of 50 µm. The filtered suspension was stained with a safranin–alcohol solution.

Table 1. Morphometric characteristics of lakes in which subfossil remains of *Rhynchotalona latens* were found in the bottom sediments.

Name of the Lake	Location	Absolute Water Level Mark, m	Area (ha)	Maximum Depth (m)	Sampling Depth (m)	Core Length (m)	Age of the Column (cal ka BP)	Vegetation Zone
Antyukh-Lambina	67°04′01.6″ N 33°18′47.2″ E	59.4	22.5	4.0	4.0	3.0	10.5	North taiga
Yujnoye Haugilampi	63°33′13.4″ N 33°20′15.7″ E	153.0	49.0	2.5	2.5	3.5	12.7	
Gahkozero	62°28′53.91″ N 35°03′09.56″ E	79.5	12.5	3.1	3.1	4.25	≈11.9	Middle taiga
Maloye Shibrozero	62°22′20.76″ N 35°12′39.60″ E	56.5	7.6	3.1	3.1	7.4	≈10.6	
Medvedevskoye	60°31′51.0″ N 29°53′57.0″ E	102.2	59	4.0	2.35/4	1/2.5	12.3	
Rubskoye	56°43′31.6″ N 40°36′23.7″ E	127.0	295	16.5	2.03	4.98	11.0	Mixed-forest zone

The samples were analyzed under Carl Zeiss Axiostar Plus and Axio Lab A1 stereomicroscopes at magnifications of 100–400×. At least 100 specimens of Cladocera were identified in each sample, and the counting of remains was carried out taking into account the pairing of some remains of the Cladocera exoskeleton: two shell flaps were counted as one carapace. The identification of the remains was carried out according to modern keys for Cladocera identification, reflecting the current taxonomy [15,16], and generally accepted definitive identification keys for Cladocera subfossil remains from European lakes [2]. In this case, the latest publications on the ecology and systematics of individual Cladocera groups by leading Russian and foreign Cladocera specialists were used [6,14]. All discovered remains of Cladocera were identified to the level of species, species group, or only to the genus if there were problems with identification. Faunal zones were identified using CONISS cluster analysis in TILIA version 2.0.b.4 [17].

Radiocarbon dating of lacustrine sediments of the studied lakes was carried out using accelerator mass spectrometry (AMS) at the Institute of Geography of the Russian Academy of Sciences, Moscow (Yuzhnoye Haugilampi Lake); at the Laboratory of Geomorphological and Palaeogeographic Studies of Polar Regions and the World Ocean, Institute of Earth Sciences, St. Petersburg (Antyukh-Lambina Lake); in the Laboratory of Ion Beam Physics, Eidgenössische Technische Hochschule (ETH), Zürich (Medvedevskoe Lake and Rubskoye Lake); and at the AMS Laboratory of Taiwan University (Medvedevskoe Lake, Gakhkozero and Maloye Shibrozero lakes) [18,19]. Calibration of radiocarbon age to calendar age was carried out using the CALIB REV 8.2 [20], Bacon 2.2 [21], and OxCal 4.2 [22] programs, with the IntCal13 and IntCal20 [23] calibration curves. Detailed information on the AMS dating results of the studied lakes is given in Subetto et al. [18] and Nazarova et al. [24].

3. Results and Discussion

Rhynchotalona latens was previously considered endemic to Finland, but several previous works have questioned this view [5,6,11,25]. Remains identified as *Unapertura latens* have been recorded from oligotrophic lakes in the Swiss Alps [26], northern Italy [27], and the Tatra mountains in Poland [28], as well as lakes in northern Canada [5,6,25]. There is also one unconfirmed record from central China [5,29]. In previous studies in Russia, no species was found in bottom sediments of lakes. Our research indicates the presence of *R. latens* in six lakes of the Kola–Karelian region and the central part of the East European Plain [11]. The species is rare even in Finland, typically as single specimens [5,6]. The very small size of *R. latens* (0.2–0.3 mm) is also a challenge in the study of the species. Lake Sylvilampi (NE Finnish Lapland) is currently the only recorded lake where *R. latens* formed a significant part of the fossil cladoceran community [5,29]. This species, which inhabits northern and alpine areas, was previously considered a glacial relict sensitive to climate change [5,6,30]. All our findings of *R. latens* were only from the lake sediments of the Late Pleistocene and Mid-Holocene. The first discovery of this species in the bottom sediments of Russia's lakes was made in 2015, when we found *R. latens* in the bottom sediments of Lake Medvedevskoye in the Karelian Isthmus (60°31′51.0″ N, 29°53′57.0″ E) [11]. Chitinous remains of the exoskeleton of seven specimens, represented by head shields and postabdomens, were found at a depth of 286–472 cm (4.2–11.16 cal ka BP). Lake Medvedevskoye is located in the Central Upland of the Karelian Isthmus at elevations of 102.2 m a.s.l. Due to its location and small watershed, the lake was never flooded by larger water bodies after deglaciation of the Karelian Isthmus and is characterized by a slow rate of continuous sedimentation, with allochthonous and aeolian components dominating the sediments [31]. The surrounding vegetation is dominated by *Pinus sylvestris*, *Picea abies*, dwarf shrubs, shrubs, lichens, and mosses. Lake Medvedevskoye has an open basin with a surface area of ca 0.46 km^2; it is 0.39 km wide and 1.22 km long, with a maximum depth of 4 m. Approximately 20% of the lake area is overgrown with macrophytes and riparian vegetation. There is almost no summer 'flowering' of the water in the lake [32].

Rhynchotalona latens is rare in sediment cores of Russia's lakes; the relative abundance of the species in the studied lakes was less than 1.0% of the total number of Cladocera remnants discovered (Figure 1). The headshields of *R. latens* bear an external resemblance to the closely related *R. falcata*, which has a different pore system, an extended midpoint of the posterior margin, and a much longer narrow rostrum [2,6]. The location and shape of the head pores are considered the main feature in the identification of Cladocera headshields. *R. latens* has a single oval median pore and two small lateral pores slightly below it [6]. The headshield is quite wide with a long, tapered rostrum and a slightly tapered posterior edge [2]. The disappearance of *R. latens* in the sediments of Lake Medvedevskoye corresponding to its current state is likely associated with a change in ecological and climatic conditions in the study region.

The taxonomic richness of the Lake Medvedevskoye Cladocera community was low at the bottom of the core and increased towards the sediment surface, along with a rise in organic content of the sediments. *Acroperus harpae*, *Bosmina* (*Eubosmina*) cf. *longispina*, *Alonella nana*, *Alonella excisa*, *Camptocercus rectirostris*, *Biapertura affinis*, and *Eurycercus* sp. were the first invaders of Lake Medvedevskoe. The dominance of the pelagic genus *Eubosmina* sp. characterizes the lake as a clear, oligotrophic, and cold-water [33,34]. However, the presence of numerous chitinous remains of Cladocera taxa closely associated with vegetation (macrophyte thickets, algae, and submerged vegetation) indicates the predominance of shallow, heavily overgrown areas in the lake. The LOI values gradually increased from 4–6% at the lowermost parts with up to 87% at the central and the upper section of composite column of the bottom sediments of Lake Medvedevskoye [24]. In the Cladocera community, the most prominent taxonomic shift coincided with an increase in the organic matter concentration between ca. 10.6 and 9.1 cal ka BP (Zone II, Figure 2). At this time, cold-water littoral (*C.* cf. *sphaericus*, *A. harpae*), oxygen variation-tolerant (*C.* cf. *sphaericus*), and planktonic cold-water oligosaprobic taxa (*B.* (*E.*) cf. *longispina*) were replaced by typical fauna associated with submerged vegetation (*Alona*, *Alonella* and *Eurycercus* sp.). There were significant changes in the composition of subfossil Cladocera communities, connected with an increase in the number of species, indicative of the changing environmental and climatic situation. *C.* cf. *sphaericus* declined and nearly disappeared from the record after 9.1 cal ka BP. Shifts in the biological communities (Cladocera and Chironomidae) and organic content of the sediments indicate that, during the Early Holocene, the lake was well oxygenated, with high water transparency [24].

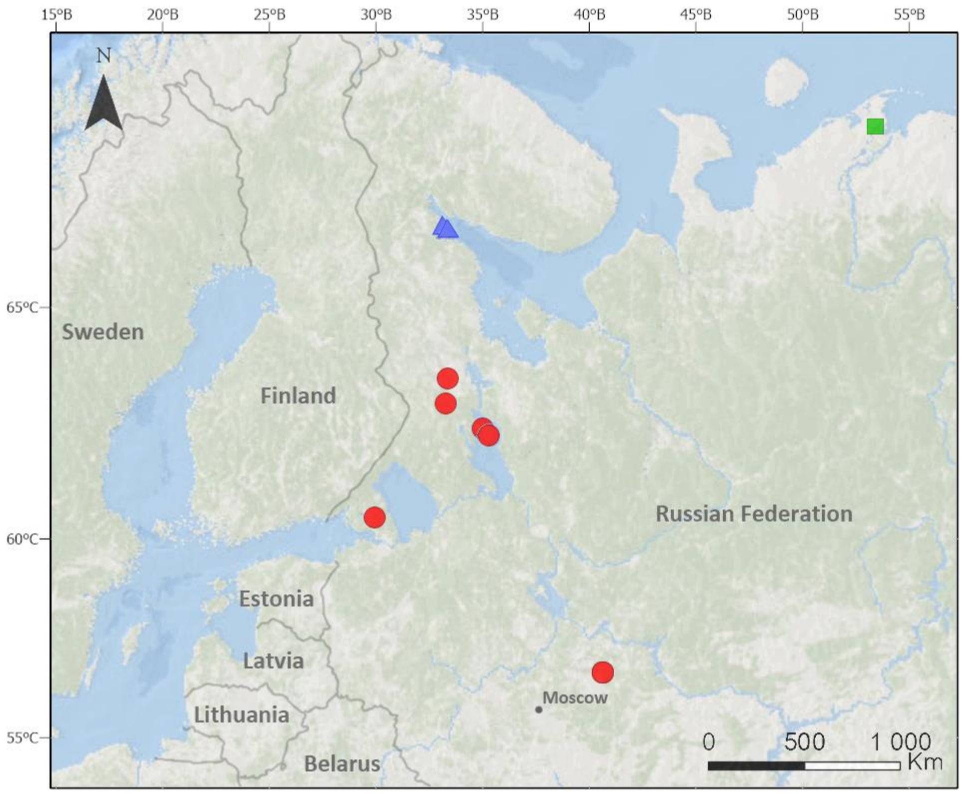

Figure 1. Findings of *Rhynchotalona latens* in the lakes of the European part of Russia: red circles—subfossil remains of the species discovered in the bottom sediments of Russia's lakes (Kola–Karelian region); green square—remains from the surface sediments of the Pechora River delta [8]; blue triangle—active population of the species in North Karelia [7].

During the Middle Holocene (8.0–4.0 cal ka BP), the abundance of littoral and phytophilic Cladocera species indicates a moderately warm climate. Between ca. 8.9 and 7.5 cal ka BP, there was a noticeable increase in the proportion of *B. affinis*, which becomes the dominant species (Zone III, Figure 2). However, after ca. 7.5 cal ka BP, there was a sharp decrease in its relative abundance in favor of the small *A. nana*, a more flexible vegetation dweller [33,34]. *Alonella nana* is closely associated with the territory of Finland. According to a number of studies, the taphocoenosis of Cladocera in the lake sediments of Finland differs markedly from that in more southern lakes, primarily by the increased relative abundance of *A. nana* [33,35–39]. There is also evidence of the presence of abundant remains of *A. nana* species in the dystrophic lakes of the Wieger National Park in Poland [40]. However, there is no mention in the literature of the significant role of the species in the lakes of the northwest of Russia. *Alonella nana* in the bottom sediments of Lake Medvedevskoye (Figure 2) reaches 50% of the total number of Cladocera remains in the Cladocera taphocoenosis at certain stages of its existence. The small dweller of vegetation is characteristic of both boreal lakes [30,41] and more northern lakes [42,43] and has even been assigned to a subarctic taxon [44]. However, this species is also strongly associated with vegetation and has a noticeable ecological preference for dystrophic lakes with *Sphagnum* mosses [30]. The pH range of *A. nana* is 4.0–10.2 [45]. The species is characteristic of acidic waters in Finland, but in North America, on the contrary, it was noted that its abundance decreases with acidification of lakes [34]. An increase in the phytophilic and acid-tolerant taxa may indicate a decrease in the stability of ecological conditions in Lake Medvedevskoye in the Middle Holocene. According to temperature reconstructions based on the analyses of the chironomid composition of bottom sediments, after ca. 7.9 cal ka BP, the reconstructed temperature in July reached maximum values, and, most likely, the littoral zones of the lake became overgrown with macrophytes, which, especially under warm conditions, contributed to paludification processes and possible oxygen depletion [24].

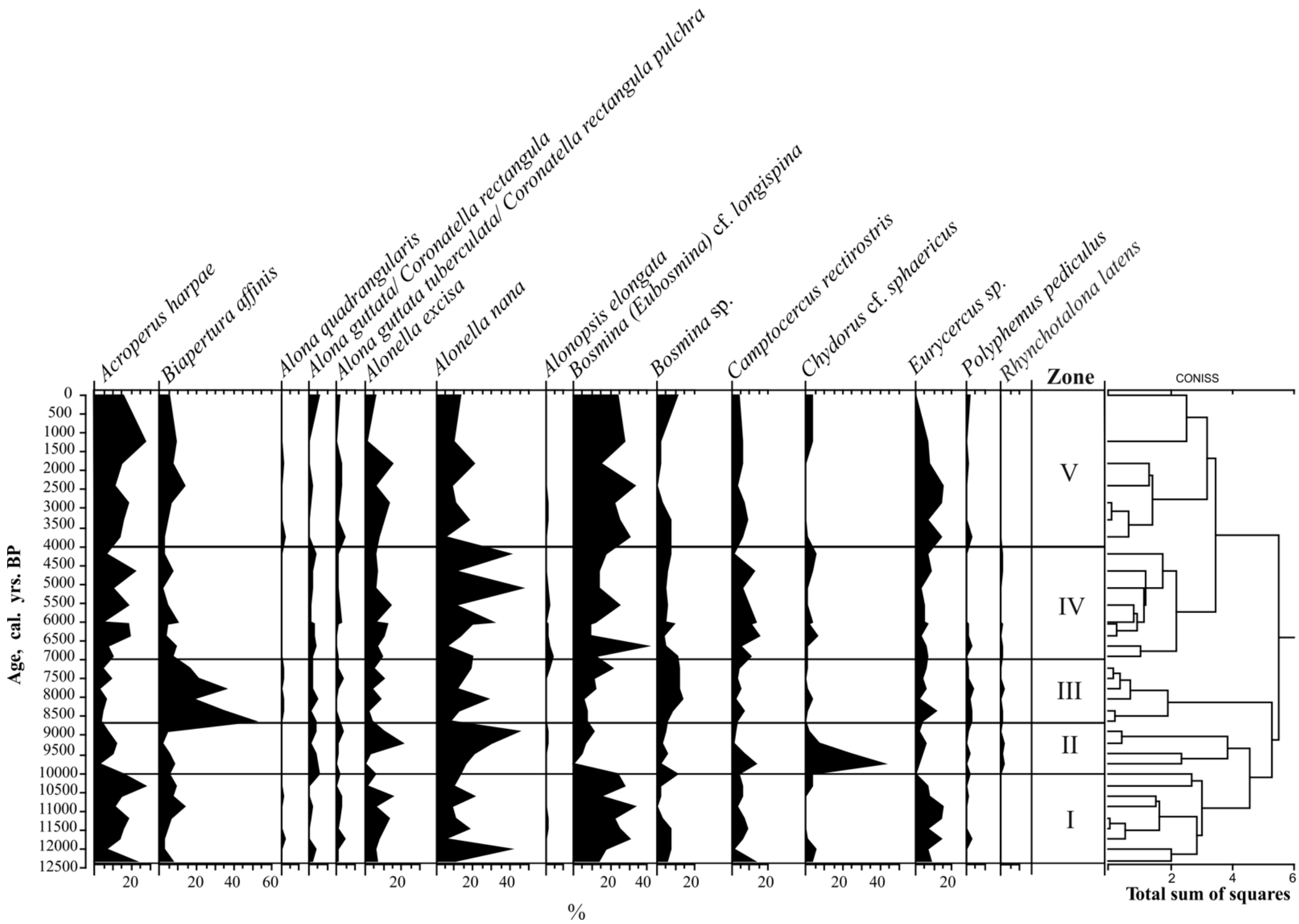

Figure 2. Stratigraphic distribution of statistically significant taxa of Cladocera in the column of bottom sediments of Lake Medvedevskoye and *Rhynchotalona latens*, Karelian Isthmus, Kola–Karelian region, European Russia. I, II, III . . . are the numbering of faunal zones.

Most remains of *R. latens* were found in the bottom sediments of Lake Medvedevskoye in the Middle Holocene; no remains of this species were found in more recent sediments (4.0 cal ka BP to present time). Moreover, in none of the lakes studied by us were the remains of *R. latens* found in the Late Holocene. Nevalainen et al. [5] noted a co-occurrence of the species pool *Alonella excisa*–*Alonopsis elongata*–*Alonella nana* together with *R. latens*. It should be noted that the listed taxa also form a significant part of the subfossil Cladocera composition of Lake Medvedevskoe, which confirms the assumption of joint occurrence of species and gives further evidence of the affiliation to vegetation-rich oligotrophic lakes and dystrophic wetland lakes. The relative abundance of these species was as follows: *A. nana*—15.35%, *A. excisa*—6.84%, and *A. elongata*—1.03%. A significant proportion of identified specimens in the sediment column in Lake Medvedevskoe belonged to *Bosmina* (*Eubosmina*) cf. *longispina* (15.49%), a typical representative of pelagic plankton, which inhabits various water bodies of northern latitudes but prefers oligotrophic conditions [34].

There was a further increase in the trophic capacity of the lake during 7.0 cal ka BP–present time (Zones IV–V, Figure 2). There was some acidification of Lake Medvedevskoye, observed as an increase in the number of acidophilic taxa, which could relate to an increase in the water level of the lake and waterlogging of the coastal area due to climate humidification [31]. Currently, Lake Medvedevskoye has a pH from 5.1 to 5.3, and the phytoplankton in the lake is dominated by raphidophyte algae, typical of stagnant basins and swamps [24]. The decrease in the proportion of the species pool *A. excisa*–*A. elongata*–*A. nana* is probably associated with changes of conditions in the water body, which are most suitable for the existence of *R. latens*. It is also likely that the disappearance of this species is related to the high content of organic matter: the concentration remained high until ca. 0.9 cal ka BP (median loss on ignition (LOI) = 85.4%) and then reduced to 42% [24]. For example, Nevalainen et al. [5] attribute road construction to the disruption of natural organic matter flux and hydrological changes in the small catchment of Lake Sylvilampi, which is probably related to further changes in the proportion of *R. latens* in the lake bottom sediments. Chironomid analysis of the sediment column of Lake Medvedevskoye revealed the dominance of thermophilic inhabitants of the littoral zone at the present stage of the lake development and some cooling in the study region [46]. The disappearance of *R. latens* from European Russia may be associated with climatic and environmental changes, in particular warming and changes in the trophic status of the studied lakes, which confirms that it is a species sensitive to the effects of global warming, as stated in Nevalainen et al. [5] and Van Damme and Nevalainen [6].

4. Conclusions

Remains of *Rhynchotalona latens*, previously unidentified in the bottom sediments of lakes of European Russia, were found in the bottom sediments of some lakes. All of the recovered remains of *R. latens* were dated to the Late Pleistocene–Mid-Holocene period; remains of this species were not found in bottom sediments corresponding to the Late Holocene. According to the data obtained and in accordance with previous studies, *R. latens* prefers conditions of cold climate and low organic matter content. The great rarity of the species in modern reports of Russia's zooplankton may be due to insufficient knowledge of the species, particularly its habitats, or to climatic and environmental changes in the study region. However, findings of the species in surface sediments and as a living population support the suggestion of previous studies that the species is associated with modern analogues of periglacial aquatic environments and may be sensitive to global warming. To better understand the geographical distribution of the species in Russia, a more detailed analysis of both modern Cladocera communities and subfossil remains in the bottom sediments of lakes in the northern regions of the country is required.

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